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Modeling of a Clothing Assembly line through the Identification Process

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Abstract*: Nowadays, a new concept called fast fashion emerged worldwide. In order to remain efficient, companies need to keep their logistics under control. For that purpose, they need to control their manufacturing and decrease their delays and costs. To achieve that, industries need to make a lot of experiments before optimizing their supply chains. This may lead to unnecessary costs and it is contrary to the company's policy. To overcome this situation, modeling and simulating could provide the best economical solution. The aim of this work is to obtain a mathematical model of an assembly line in the textile and clothing industry. The system will be represented by a black box with a real set of data collected from the industry. This model will have to reflect as faithfully as possible the studied system.

Keywords: System Identification; Difference equations; Z-Transform ; Modeling; Supply chain; Production; Complexity

I. INTRODUCTION

The textile and clothing industry has a very complex supply chain due to the seasonality of the trade and a commodity that is obsolete very quickly.

To be competitive and responsive, companies must optimize their human and material resources, and make their manufacturing costs lower to maximize profits.

Today, a new concept has emerged: The Fast fashion. From the Pattern to storage at store, the process should not last more than fifteen days. These are the new constraints of the sector.

To achieve this, it is imperative to experiment with new opportunities and to have the most attractive prices. It would therefore be advisable to reduce its costs considerably. Before reaching an optimum level of service and low costs, it is necessary to experiment with several options.

But this would generate unnecessary costs before reaching an optimal result, which would run contrary to the company's policy. Modeling logistics systems, remains the most efficient and effective solution to achieve the expected result without experimenting and therefore without unnecessary costs.

The interest to model is to describe as faithfully as possible our logistics system, but also to obtain a mathematical model that will allow us to order our system thereafter.

As described by Ljung, establishing a model from observed data is crucial in science [1].

To obtain a mathematical model from actual observed and measured data is the principle of the theory of systems identification.

Modeling logistics systems, especially production systems using the theory of identification has been carried out in some previous work.

H.Sarir et al, adopted the identification approach in 2013 to model an assembly line [2].

In 2014, Rachad et al, identify a production system, using the ARX model[3]. A second work was carried out for the identification of the production systems by making a comparison between the two models ARX and ARMAX [4].

Fouraiji et al. chose to use the NARX and HAMMERSTEIN & WIENER models to identify their production system [5].

Previous work has been done to identify an assembly line in the textile industry through a graphic identification method: the Broida method [6].

The objective of this work will be to identify an assembly system in the textile and clothing industry, in order to describe it and study its behavior by modeling and estimating it through a transfer function that describes it as accurately as possible.

II. SYSTEM IDENTIFICATION

The concept of the identification of complex dynamical systems began in 1956 by L. Zadeh[7]. It defines the concept of identification as: Determination, based on observation of inputs and outputs, of a system in a specified class of systems to which the system under test is equivalent; Determination of the initial or final state of the tested system [8].

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Identification is a type of modeling that is based on observing the temporal behavior of the inputs and outputs of a system. These so-called models of representation are developed from experimental measurements[9].

The principle of identification theory is illustrated as follows[10]:

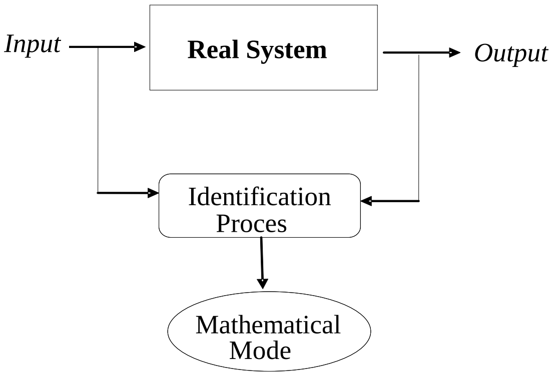

Fig. 1 System Identification Principle

The procedure of identification is done according to four essential points:

- Acquisition of data.
- Estimation of the model from the data.
- Choice of the model which is the closest to the real system according to the desired criterion.
- Validation of the model.

The case study is applied to a supply chain in the textile and clothing sector.

The studied system is an assembly line of a single product. The inputs and outputs of the system are described as such:

Fig. 2 Real System

With:

- $u(n)$: Quantity of Finished Product ordered by the Customer.
- $y(n)$: Quantity of finished product delivered to the customer

This process is of major importance in the internal supply chain.

Its mission is to manufacture the items requested by the customer respecting the quality and quantity required.

For this process, the work process begins with the reception of the Production Orders: OF as well as the Raw Materials: MP, and ends with the storage of the quantity produced in the storage area.

A. Acquisition of data.

The first step of the identification procedure is to measure and record the input data $u(t)$ and output $y(t)$ of a complex dynamic real system. As a result, we obtain our Working Data (Fig. 3). The system is considered as a black box.

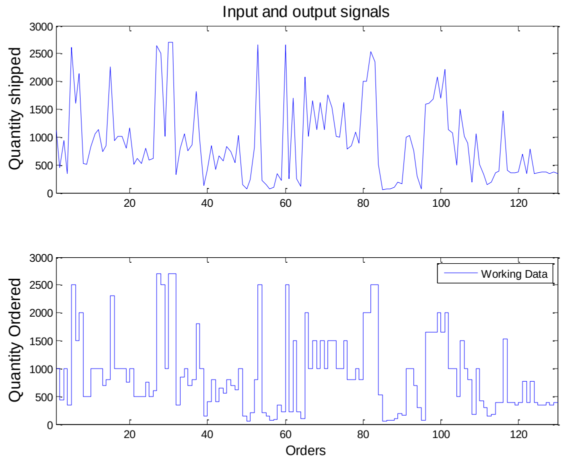

Fig. 3 Working Data

B. Estimation of the model from the data.

This second step consists of choosing a model that would describe as accurately as possible the real system. There are several models to identify a dynamic system: ARX, ARMAX, OE, BJ ...

A time-invariant linear system SLIT is described by its input u (t) and an output y (t). We can therefore model the system using a constant coefficient difference equation such as [11]:

$$y(n) + a_1 y(n-1) + \cdots + a_N y(n-k) = b_1 u(n-1) + \cdots + b_M u(n-k)$$

With:

- $y(n)$: Outputs (1)
- $u(n)$: Inputs

This equation can be formulated in another way such as:

$$y(n) = -a_1 y(n-1) + \cdots - a_N y(n-k) + b_1 u(n-1) + \cdots + b_M u(n-k) \quad (2)$$

For a more compact writing, we get [14]:

$$y(n) = -\sum_{k=1}^{N} a_k y(n-k) + \sum_{k=1}^{M} b_k u(n-k) \quad (3)$$

By applying the transform in Z, one obtains [14]:

$$\mathrm{Y(z)} = -\sum_{\mathrm{k=1}}^{\mathrm{N}} \mathrm{a_k z^{-k} Y(z)} + \sum_{\mathrm{k=1}}^{\mathrm{M}} \mathrm{b_k z^{-k} U(z)} \quad (4)$$

This allows us to estimate through the inputs and outputs of the system, the transfer function that will describe the actual system.

(5)

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$$H(z) = \frac{Y(z)}{U(z)} = \frac{\sum_{k=1}^{M} b_k z^{-k}}{1 + \sum_{k=1}^{N} a_k z^{-k}}$$

With:

$H(z)$: System Transfer Function

As a result of the constant coefficient difference equations, we obtain our model in the form of a Transfer Function.

The choice of the model must be made according to a criterion of the best possible adjustment. This allows us to verify how much our model describes the real system as accurately as possible. Fig. 4 present the comparison between the measured output which is actually our real data, and the model's output.

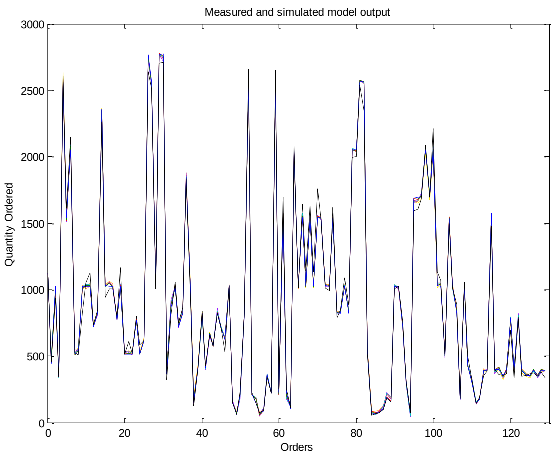

Fig. 4 Measured and simulated model output

C. Choice of the model which is the closest to the real system according to the desired criterion.

The best fit criterion is to compare the measured outputs that belong to the real system, with the estimated outputs of the model.

$$\text{Best Fit} = \left(1 - \frac{|y-\hat{y}|}{|y-\bar{y}|}\right) * 100 \qquad (6)$$

With:

- y: Actual outputs measured
- $\hat{y}$: Model Estimated Outputs
- $\bar{y}$: Average of Actual Outputs

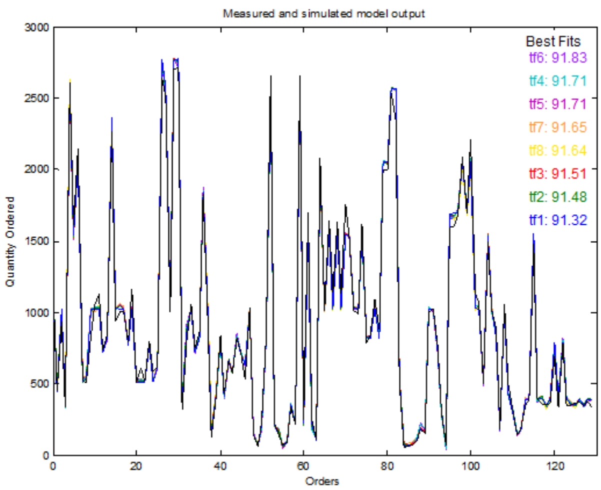

Fig. 5 Choice of the best Model

As we can see in the Fig. 5, several attempts have been made (by changing the number of roots and zeros) to find the closest model which represent the best our real system. According to the best fit criterion, we may choose the transfer function number six (Fit to real data to: 91,83%).

D. Validation of the model.

The validation of the model consists of checking if the criterion of the best fit is still valid even with another set of data, but harvested under the same conditions as the initial data collected and used to obtain the first model (Working Data). The Fig. 6 here represents the new set of data, which we will use to validate the model. As shown in the Fig. 6, the validation data is different than the working data; even it was collected in the same conditions and with the same way.

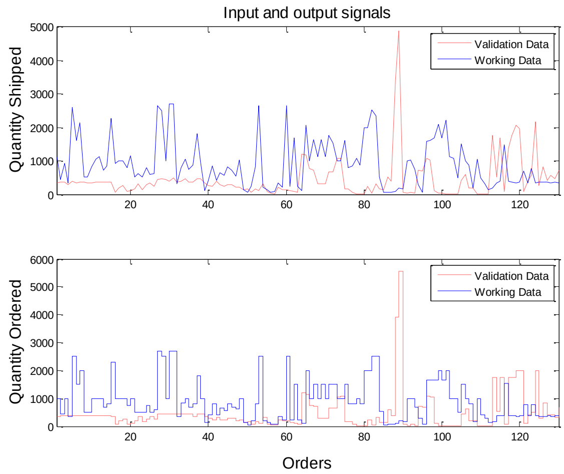

Fig. 6 New set of data for model validation

III. COMPLEXITY

A model should never be too complex. The purpose of modeling and identification is to control the system in order to optimize the resources allocated to the system.

To obtain a model that is too complex would create difficulties in controlling and controlling it.

Among the criteria for verifying the complexity of the estimated model is the Akaike Information Criterion (AIC)[12].

The lower the Akaike criterion, the less complex the model is and the better quality and precision are.

The principle is the same as for the validation of the model, because it is to obtain the criterion AIC with another set of data (Validation Data)

The AIC criterion is described by the following formula:

$$AIC = N * \log\left(\det\left(\frac{1}{N}\sum_{1}^{N} \varepsilon(t,\hat{\theta}_N)\left(\varepsilon(t,\hat{\theta}_N)\right)^T\right)\right) + 2n_p + N * \left(n_y * (\log(2\pi) + 1)\right) \qquad (7)$$

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With:

- N: Number of values present in the estimation data set
- $\varepsilon(t)$: is a vector for the prediction error
- θ_N: represents the estimation parameters
- np: represents the number of estimated parameters
- ny: represents the number of estimated outputs of the model.

IV. RESULTS

Several attempts have been made by changing the number of poles and zeros in order to increase the rate of the Best Fit and thus get as close as possible to the real system. We note that the more we increase the number of degrees, the greater the reliability of the model is.

The model finally obtained must be validated with a new set of data collected under the same initial conditions. The new outputs calculated through the model which is in the form of a transfer function, are therefore compared to the new data collected and through the same criterion (Best Fit), the model is supposed to be always valid.

Table- I: Summary of all models

Models	Nbr Roots	Nbr Zeros	Best Fit Criterion	Best Fit for Validation	AIC
$H_{(1,0)}(Z)$	1	0	91.32 %	83.89%	8.3156
$H_{(2,1)}(Z)$	2	1	91.48 %	84.16%	8.3344
$H_{(3,2)}(Z)$	3	2	91.51 %	84.22%	8.3834
$H_{(4,3)}(Z)$	4	3	91.71 %	84.15%	8.3975
$H_{(5,4)}(Z)$	5	4	91.71 %	84.81%	8.4703
$H_{(6,5)}(Z)$	6	5	91.83 %	84.36%	8.5026
$H_{(7,6)}(Z)$	7	6	91.65 %	84.62%	8.6288
$H_{(8,7)}(Z)$	8	7	91.64 %	85.32%	8.7234

The Table1, shows a synthesis of all the models and how they represent the real system. We can see that the closer we get to represent faithfully our real data ($H_{(8,7)}(Z)$ with a Best Fit Criterion: 91.64%) the model is getting more complex (AIC= 8.7234). But, with a less complex model like $H_{(1,0)}(Z)$ (AIC= 8.3156), we may notice that the best fit criterion is still good for this model and still represents faithfully our real data with a Best Fit Criterion: 91.32%. The difference between the two best fit criterions is really small.

Therefore, the transfer function that describes our system is in the following form:

$$H(z) = \frac{1{,}024}{1-0{,}002977z^{-1}} \qquad (8)$$

V. CONCLUSION

The objective of this paper is to use mathematical and automatic tools like difference equations and the z-transform through the identification approach in order to model a supply chain, with an application into a real case in the clothing industry.

Then we had to choose the model which describes the best the real system data and the criterion of comparison was the best fit criterion.

After validation with a new set of data, the system is still good ($H_{(8,7)}(Z) = 85.32\%$).

To study and to reduce the complexity of the model, we chose to use the Akaike's criterion (AIC). As a result, the less complex model has also a good fit and is representing faithfully the real system.

Table- II: Transfer function's Caracteristics

Models	Nbr Roots	Nbr Zeros	Best Fit Criterion	Best Fit for Validation	AIC
$H_{(1,0)}(Z)$	1	0	91.32 %	83.89%	8.3156

As a perspective that is based on our modeling results, the next step will be the control of this system for an optimization purpose.

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